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Sulejmani

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(54) **QUEUE WAIT TIME ESTIMATION**

(71) Applicant: **Musa Sulejmani**, Mahomet, IL (US)

(72) Inventor: **Musa Sulejmani**, Mahomet, IL (US)

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H04W 4/02 (2018.01)
H04W 4/021 (2018.01)

(52) **U.S. Cl.**
CPC **G06Q 30/0281** (2013.01); **H04W 4/021** (2013.01); **H04W 4/026** (2013.01); **H04W 4/027** (2013.01)

(58) **Field of Classification Search**

CPC H04W 4/025; G01S 5/0284
USPC 455/456.1, 456.3, 456.6, 404.2; 340/501, 340/328

See application file for complete search history.

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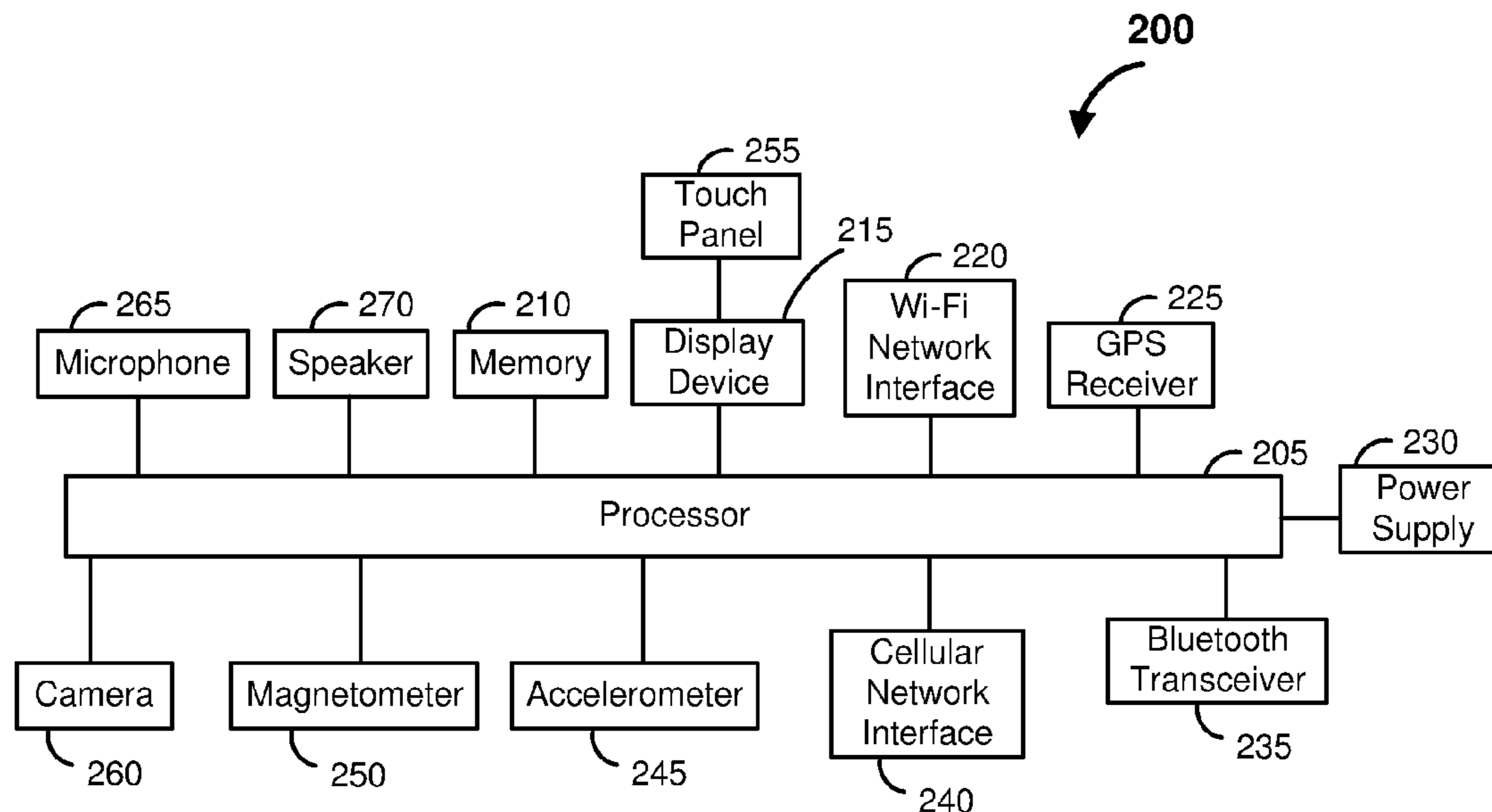
Primary Examiner — Kiet M Doan

(74) *Attorney, Agent, or Firm* — Duane Morris LLP

(57) **ABSTRACT**

The queue wait time estimation system of the present disclosure leverages its users' Internet-connected mobile devices—and the data they generate based on sensor feedback—to estimate the queue wait times at various establishments. The queue wait time estimation system communicates the estimated queue wait times to the users to enable the users to make an informed decision as to whether they'd like to visit a particular establishment based on its estimated queue wait time.

18 Claims, 5 Drawing Sheets



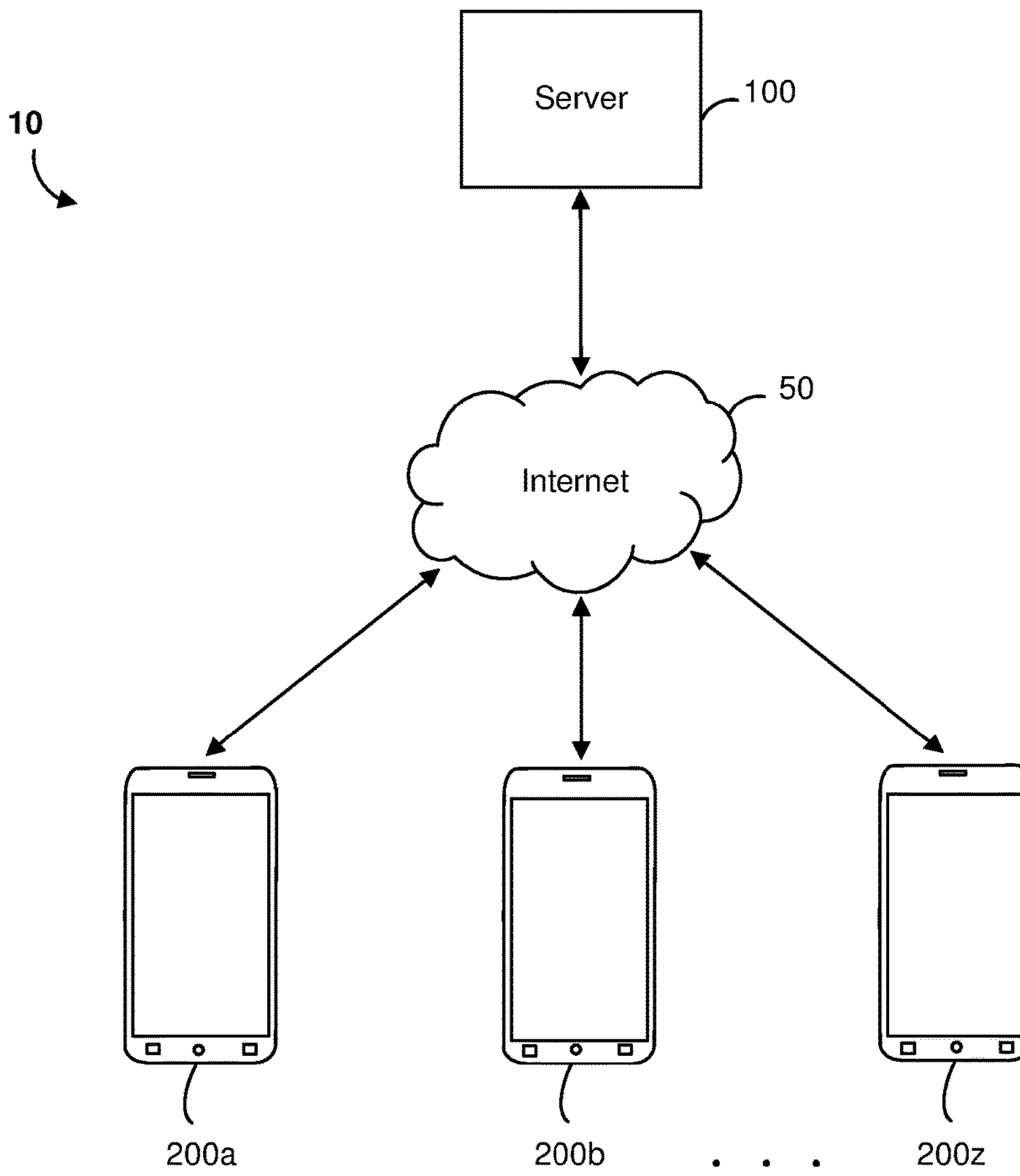


Figure 1

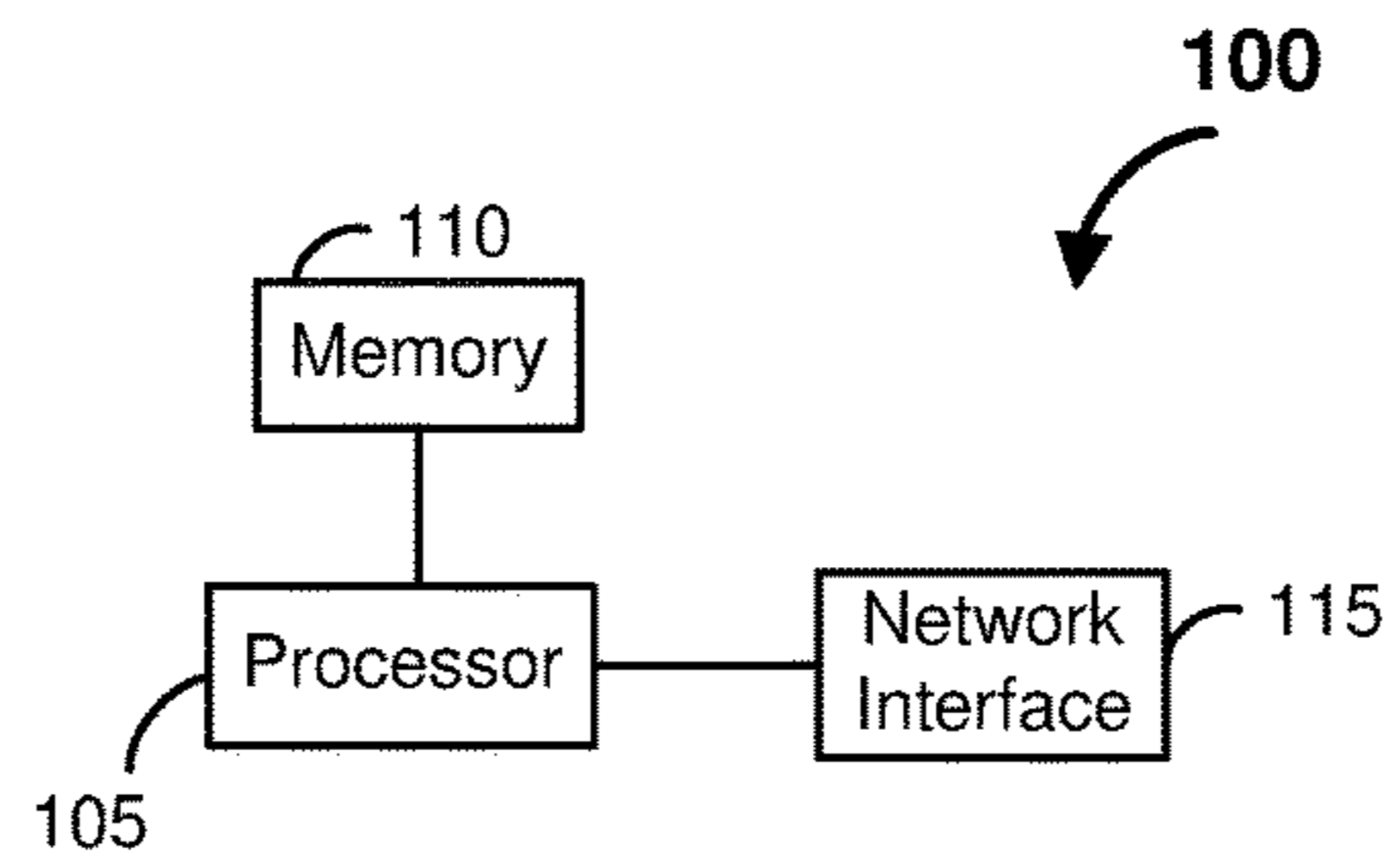


Figure 2

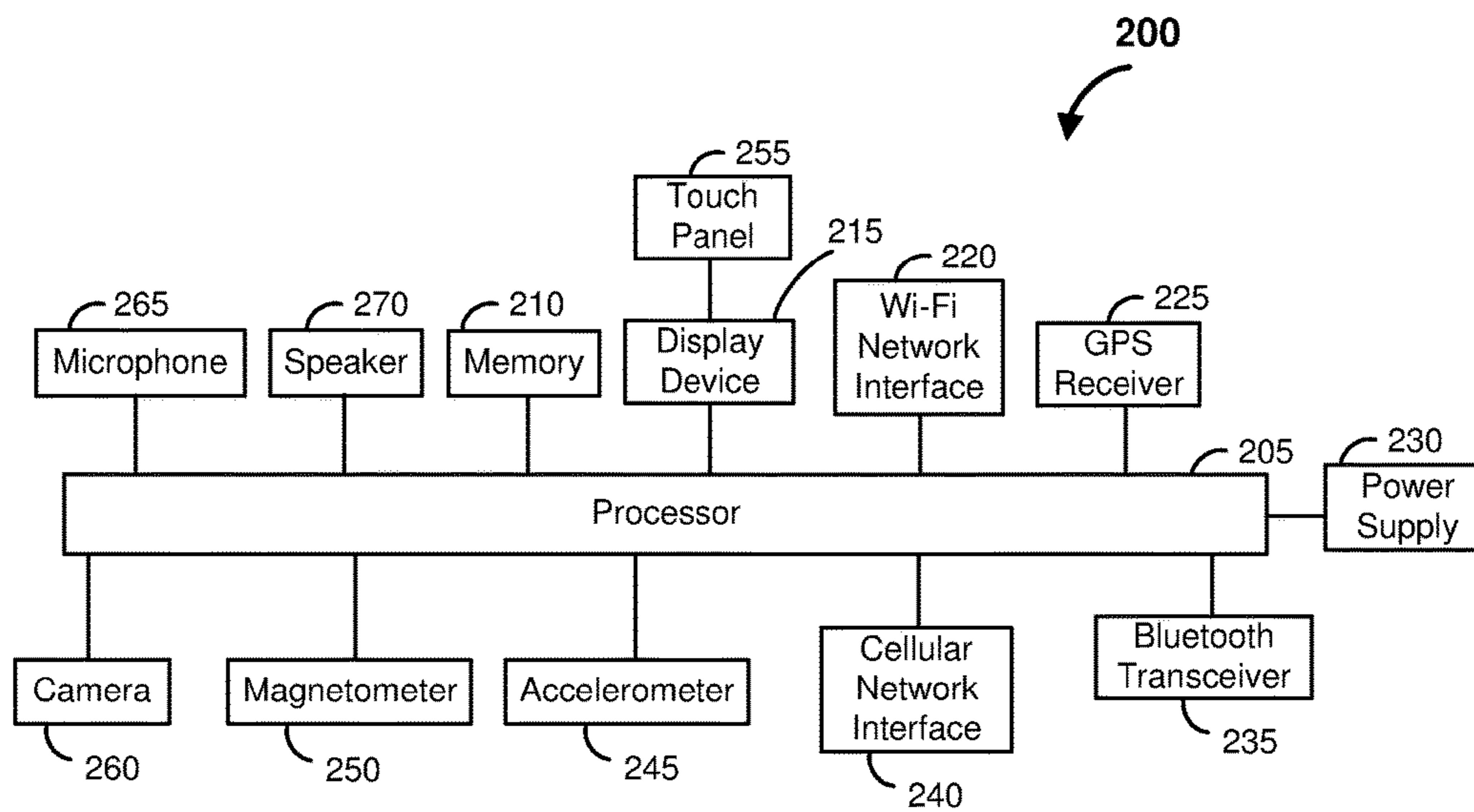


Figure 3

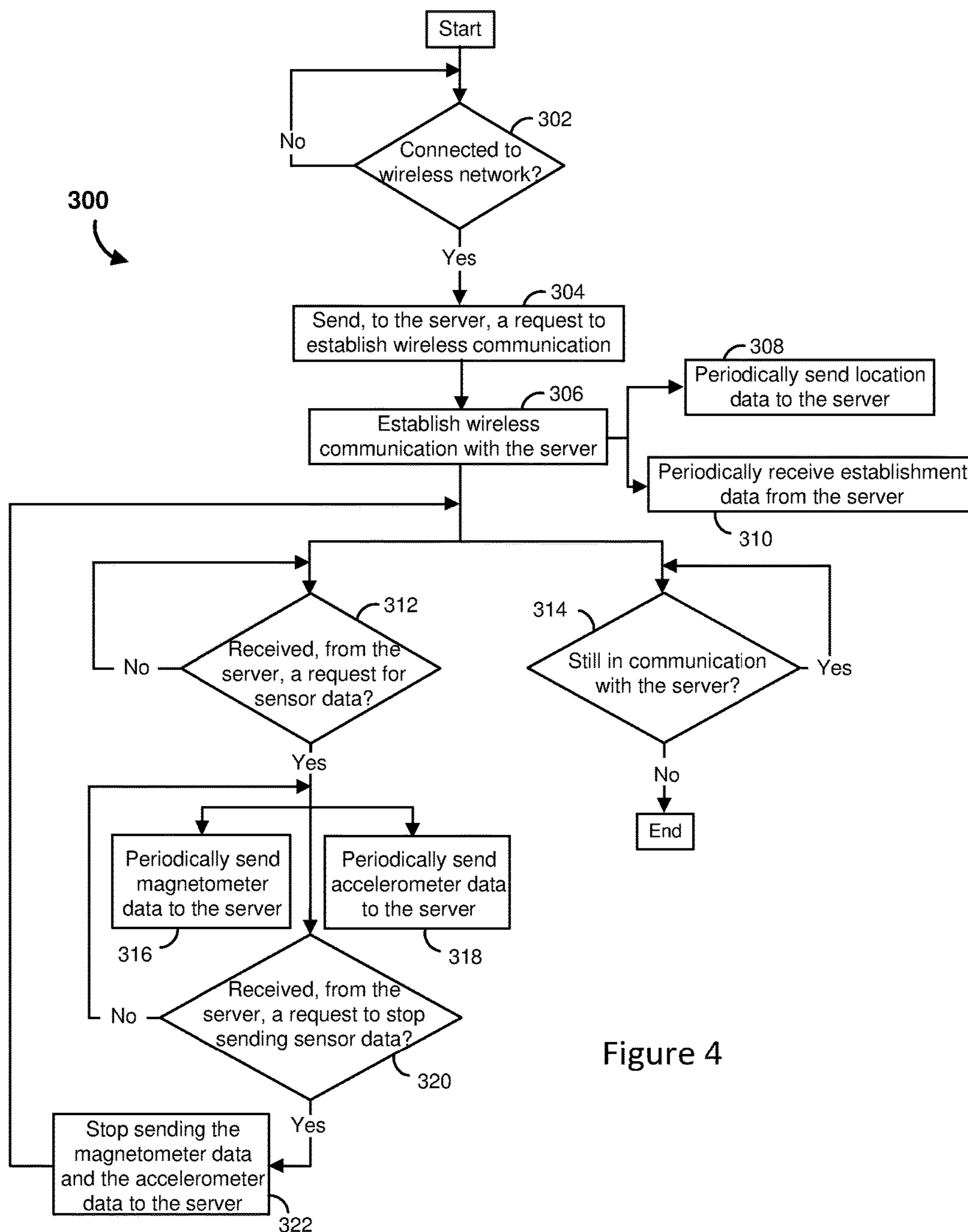


Figure 4

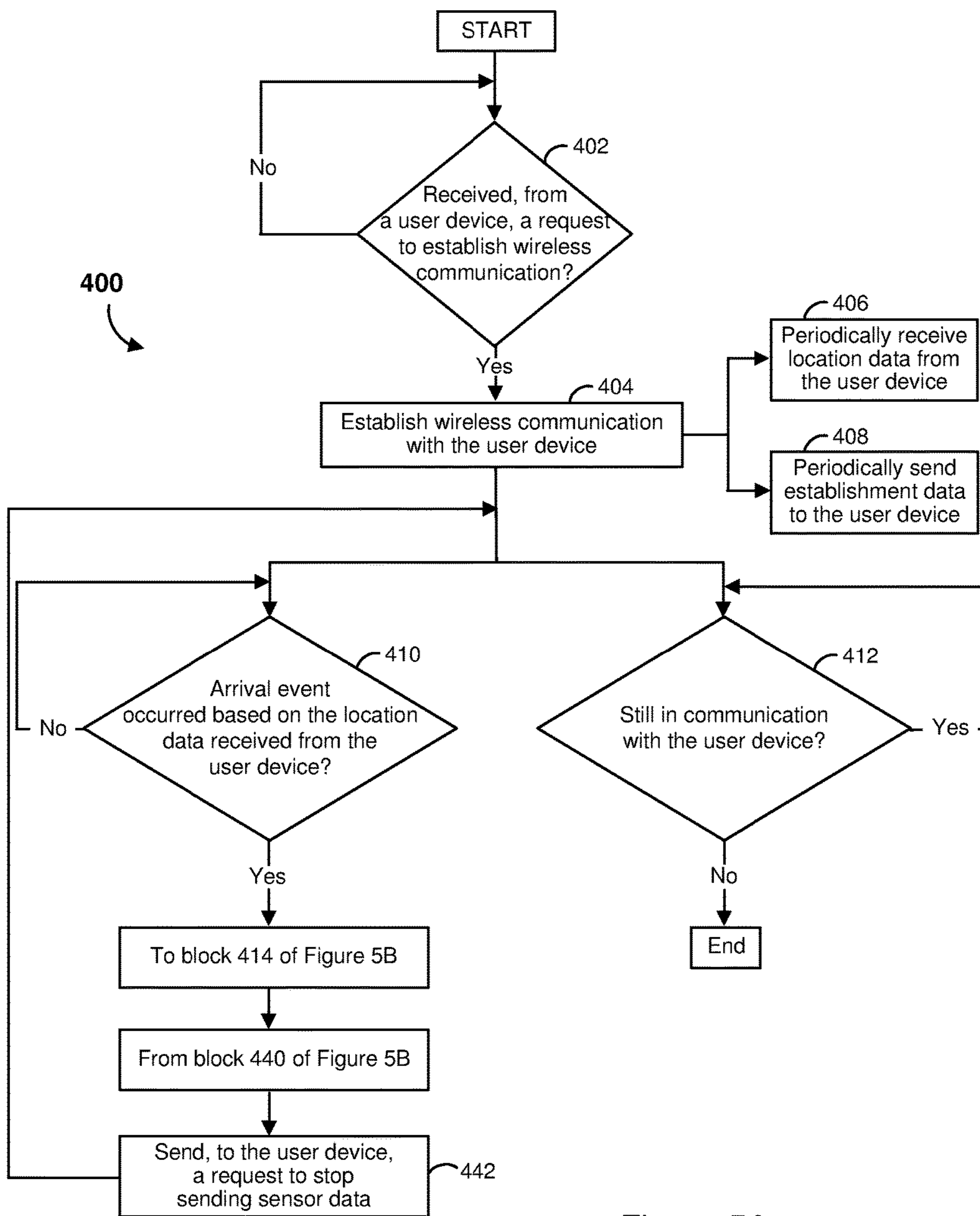
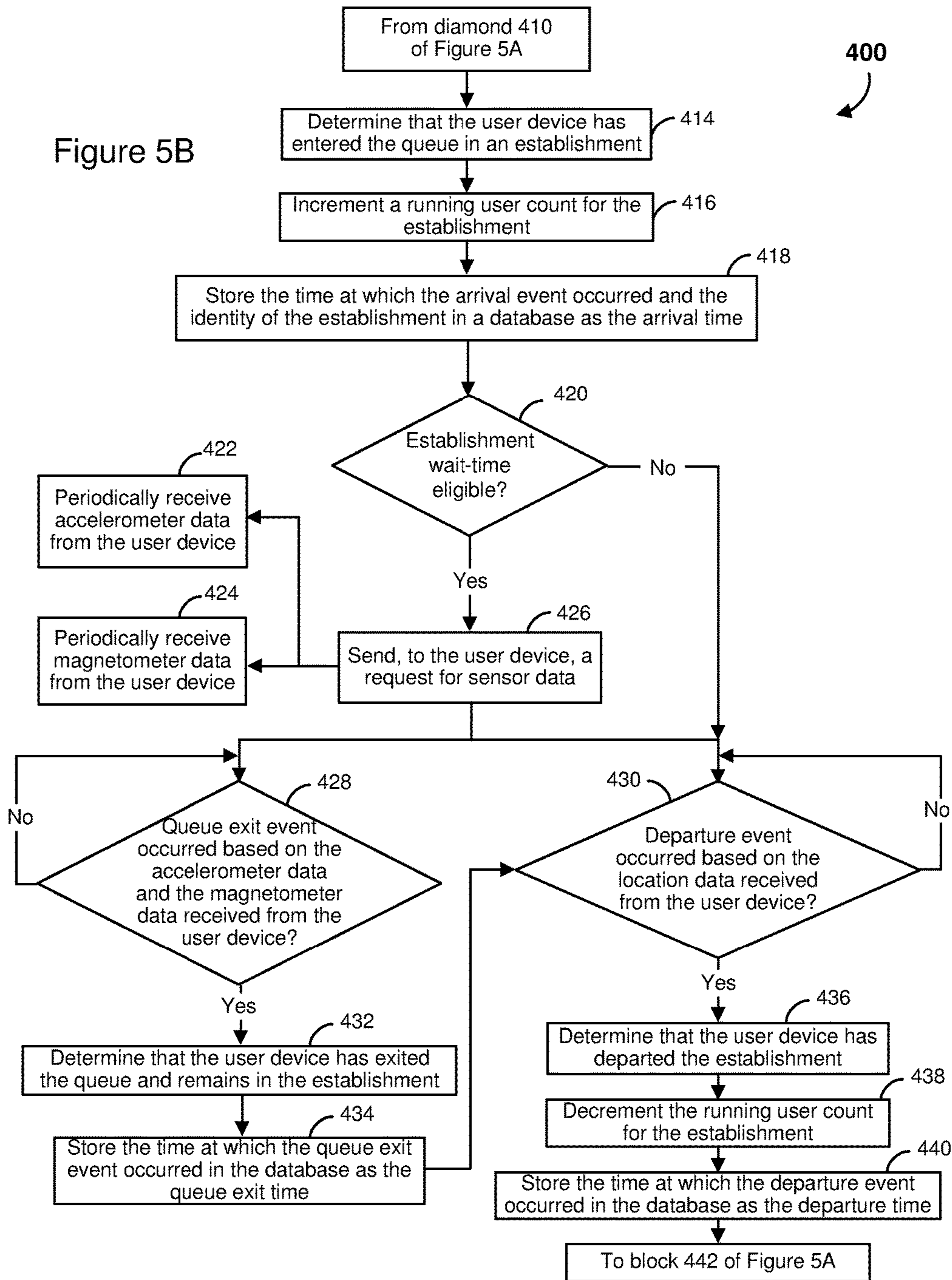


Figure 5A

Figure 5B



1**QUEUE WAIT TIME ESTIMATION**

PRIORITY CLAIM

The present application is a continuation of U.S. patent application Ser. No. 15/636,051 to M. Sulejmani (filed on Jun. 28, 2017), which claims priority to U.S. Provisional Patent App. No. 62/364,601 to M. Sulejmani (filed on Jul. 20, 2016). Both of these prior applications are hereby incorporated by reference.

BACKGROUND

People dislike waiting in queues (or lines), be it for their morning coffee or their lunchtime burrito. Free time is especially prized for certain people, and wasting it standing in a queue is frustrating and stressful. For example, someone who undergoes dialysis 10 to 12 hours each day for months at a time can't afford to spend precious free time standing in a queue. With Americans alone spending tens of billions of hours each year waiting in queues, there is a need for new technology that enables people to reduce the amount of time they wait in queues.

SUMMARY

The queue wait time estimation system of the present disclosure leverages its users' Internet-connected mobile devices—and the data they generate based on sensor feedback—to estimate the queue wait times at various establishments. The queue wait time estimation system communicates the estimated queue wait times to the users to enable the users to make an informed decision as to whether they'd like to visit a particular establishment based on its estimated queue wait time. No longer will a user step out for a quick coffee break to unexpectedly find himself stuck in a 20-minute queue for a latte.

In various embodiments, for a given user, the queue wait time estimation system uses: (1) location data (such as global positioning system (GPS) coordinates) from the user's mobile device (such as a smart phone) to determine when the user arrives at an establishment, which the queue wait time estimation system assumes is the time the user enters the queue at the establishment; (2) sensor data obtained from sensors on the user's mobile device (such as accelerometers and a magnetometer) to determine when the user exits the queue; and (3) location data from the user's mobile device to determine when the user departs the establishment. The queue wait time estimation system uses this data to determine the amount of time the user spent waiting in the queue at the establishment, called the queue wait time. The queue wait time estimation system determines queue wait times for numerous users who visit the establishment, and uses some of these individual queue wait times to determine an estimated queue wait time for the establishment that reflects how long a person will likely wait in the queue when visiting the establishment.

In certain embodiments, the queue wait time estimation system also maintains a running count of the quantity of queue wait time estimation system users in each establishment. The queue wait time estimation system uses this running count to estimate a total quantity of people in each establishment.

Responsive to users' requests, the queue wait time estimation system communicates the estimated queue wait time for the establishment (and optionally the estimated total quantity of people in the establishment) to the users, such as

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via a queue wait time estimation application installed on the users' mobile devices. This enables the users to make informed decisions as to whether to visit the establishment.

Additional features and advantages are described in, and will be apparent from, the following Detailed Description and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a block diagram of one example embodiment of the queue wait time estimation system of the present disclosure.

FIG. 2 is a block diagram of one example embodiment of a server of the queue wait time estimation system of FIG. 1.

FIG. 3 is a block diagram of one example embodiment of a user device—a mobile phone—of the queue wait time estimation system of FIG. 1.

FIG. 4 is a flowchart of an example process of operating the queue wait time estimation system of FIG. 1 from the perspective of the user device of FIG. 3.

FIGS. 5A and 5B are a flowchart of an example process of operating the queue wait time estimation system of FIG. 1 from the perspective of the server of FIG. 2.

DETAILED DESCRIPTION

The queue wait time estimation system of the present disclosure leverages its users' Internet-connected mobile devices—and the data they generate based on sensor feedback—to estimate the queue wait times at various establishments. The queue wait time estimation system communicates the estimated queue wait times to the users to enable the users to make an informed decision as to whether they'd like to visit a particular establishment based on its estimated queue wait time.

The following numbered headings are included for clarity, and do not limit the scope of the present disclosure.

1. Hardware

FIG. 1 shows one example embodiment of the queue wait time estimation system **10** including a server **100** communicatively connectable to a plurality of user devices **200a**, **200b**, . . . **200z** via the Internet **50** (or any other suitable data network). While the server **100** is shown as a single server, the server **100** may comprise multiple servers or other suitable computing devices.

FIG. 2 is a block diagram of one example embodiment of the server **100**, which includes: (1) a server processor **105**; (2) a server memory **110**; and (3) a server network interface **115**.

The server processor **105** is configured to execute program code or instructions stored on the server memory **110** to control operation of the server **100**. The server processor **105** may be a general-purpose processor; a content-addressable memory; a digital-signal processor; an application-specific integrated circuit; a field-programmable gate array; any suitable programmable logic device, discrete gate, or transistor logic; discrete hardware components; or any combination of these. The server processor **105** may be a microprocessor, a controller, a microcontroller, or a state machine. It may also be implemented as a combination of computing devices, such as a combination of a digital signal processor and a microprocessor, a plurality of microprocessors, or one or more microprocessors in conjunction with a digital signal processor core.

The server memory **110** is configured to store, maintain, and provide data as needed to support the functionality of the server **100**. For instance, in various embodiments, the server

memory **110** stores program code or instructions executable by the server processor **105** to control operation of the server **100**. The server memory **110** may be any suitable data storage device, such as one or more of: (1) volatile memory (e.g., RAM, which can include non-volatile RAM, magnetic RAM, ferroelectric RAM, and any other suitable forms); (2) non-volatile memory (e.g., disk memory, FLASH memory, EPROMs, EEPROMs, memristor-based non-volatile solid-state memory, etc.); (3) unalterable memory (e.g., EPROMs); and (4) read-only memory.

The server network interface **115** is configured to connect the server **100** to a wireless network—such as the Internet, a local area network, or a cellular network—and to facilitate bidirectional communication between the server **100** and other devices connected to that wireless network.

FIG. **3** is a block diagram of one example embodiment of a user device **200**, which is a mobile phone and includes: (1) a user device processor **205**; (2) a user device memory **210**; (3) a display device **215**; (4) a Wi-Fi network interface **220**; (5) a GPS receiver **225**; (6) a power supply **230**; (7) a Bluetooth transceiver **235**; (8) a cellular network interface **240**; (9) an accelerometer **245**; (10) a magnetometer **250**; (11) a touch panel **255**; (12) a camera **260**; (13) a microphone **265**; and (14) a speaker **270**.

The user device processor **205** is configured to execute program code or instructions stored on the user device memory **210** to control operation of the user device **200**. The user device processor **205** may be a general-purpose processor; a content-addressable memory; a digital-signal processor; an application-specific integrated circuit; a field-programmable gate array; any suitable programmable logic device, discrete gate, or transistor logic; discrete hardware components; or any combination of these. The user device processor **205** may be a microprocessor, a controller, a microcontroller, or a state machine. It may also be implemented as a combination of computing devices, such as a combination of a digital signal processor and a microprocessor, a plurality of microprocessors, or one or more microprocessors in conjunction with a digital signal processor core.

The user device memory **210** is configured to store, maintain, and provide data as needed to support the functionality of the user device **200**. For instance, in various embodiments, the user device memory **210** stores program code or instructions executable by the user device processor **205** to control the user device **200**. The user device memory **210** may be any suitable data storage device, such as one or more of: (1) volatile memory (e.g., RAM, which can include non-volatile RAM, magnetic RAM, ferroelectric RAM, and any other suitable forms); (2) non-volatile memory (e.g., disk memory, FLASH memory, EPROMs, EEPROMs, memristor-based non-volatile solid-state memory, etc.); (3) unalterable memory (e.g., EPROMs); and (4) read-only memory.

The display device **215** is configured to display images and video responsive to signals received from the user device processor **205**. In various embodiments, the display device includes, without limitation: a liquid-crystal display, a display based on light-emitting diodes (LEDs), a display based on a plurality of organic LEDs, a display based on polymer LEDs, a display based on a plurality of surface-conduction electron emitters, a display including a projected or reflected image, a plasma display, or any other suitable display mechanism.

The touch panel **255** enables a user to provide different inputs to the user device **200**. The touch panel **255** is overlaid atop the display device **215** and enables a user to

provide various inputs to the user device **200** by performing any of a variety of different touch operations (e.g., touching and releasing the touch panel, swiping the touch panel, and double tapping the touch panel) with her finger or a compatible stylus, depending on the embodiment. The touch panel **255** is configured to send the coordinate data of the detected location of the input touch operation to the user device processor **205**, which is configured to control the user device **200** to perform an operation responsive to the received touch input. In this example embodiment, the touch panel **255** is a capacitive touch panel, though the user device **200** may include any suitable type of touch panel (such as a resistive touch panel).

The Wi-Fi network interface **220** is configured to connect the user device **200** to a wireless network—such as the Internet or a local area network—and to facilitate bidirectional communication between the user device **200** and other devices connected to that wireless network.

The GPS receiver **225** is configured to acquire geolocation data from one or more remote sources (such as one or more GPS satellites) and to send that geolocation data to the user device processor **205**. The user device processor **205** is configured to use the geolocation data to determine information relating to the absolute position of the user device **200** on the Earth or a relative position of the user device **200** on the Earth as compared to another absolute position on the Earth (such as the absolute position of a restaurant the user wants to visit).

The power supply **230** includes a battery, such as a lithium-polymer battery, a lithium-ion battery, a nickel-metal-hydride battery, a nickel-cadmium battery, or any other suitable rechargeable or non-rechargeable power supply sufficient to power the components of the user device **200**.

The Bluetooth transceiver **235** is configured to wirelessly pair the user device **200** to another Bluetooth-enabled device and to facilitate bidirectional communication between the user device **200** and the other Bluetooth-enabled device.

The cellular network interface **240** is configured to connect the user device **200** to a cellular network and to facilitate bidirectional communication between the user device **200** and other devices connected to the cellular network.

The accelerometer **245** is configured to detect acceleration data of the user device **200** on two or three axes and to transmit the acceleration data to the user device processor **205**. The user device processor **205** is configured to use the acceleration data to determine the motion and orientation of the user device **200**.

The magnetometer **250** is configured to measure the Earth's magnetic field, determine the direction of the Earth's magnetic North, and transmit data representing the direction of the Earth's magnetic North to the user device processor **205**. The user device processor **205** is configured to use the GPS coordinates of the mobile phone and a global map of declination angle (the angle between the Earth's true North and the Earth's magnetic North) to determine a required correction angle. The user device processor **205** is configured to apply the required correction angle to the direction of the Earth's magnetic North to obtain the direction of the Earth's true North. The magnetometer **250** thus enables digital compass functionality on the user device **200**.

The camera **260** is any suitable camera configured to capture still images or video, which are stored in the user device memory **210**.

The microphone **265** and the speaker **270** are suitable devices respectively configured to receive and output sound, and may interface with suitable analog-to-digital and digital-to-analog converters.

2. Operation

2.1 User Device/Server Interaction-User Device Perspective

FIG. **4** is a flowchart of an example process **300** of operating the queue wait time estimation system **10** from the perspective of the user device **200**. In various embodiments, a set of instructions stored in the user device memory **210** and executed by the user device processor **205** represents the process **300**. Although the process **300** is described with reference to the flowchart shown in FIG. **4**, many other processes of performing the acts associated with this illustrated process **300** may be employed. For example, the order of certain of the illustrated blocks or diamonds may be changed, certain of the illustrated blocks or diamonds may be optional, or certain of the illustrated blocks or diamonds may not be employed.

In this example embodiment, a queue wait time estimation application must be installed on the user device **200**—such as on the user device memory **210**—before the user device **200** can communicate with the server **100** as described below. The queue wait time estimation application enables communication between the server **100** and the user device **200**, which enables the user device **200** to display (or otherwise output) establishment data received from the server **100** for one or more establishments. Establishment data includes, for a particular establishment: (1) an estimated queue wait time (available if the establishment is queue-wait-time eligible); and/or (2) an estimated total quantity of patrons currently in the establishment (available in certain embodiments).

The process **300** begins with the user device **200** monitoring for connection to a suitable wireless network—such as the Internet or a cellular network—over which the user device **200** can communicate with the server **100**, as diamond **302** indicates. In this example embodiment, the user device **200** is configured to communicate with the server **100** whenever the user device **200** is connected to a network that facilitates communication with the server **100**. That is, in this embodiment, the queue wait time estimation application need not be open on the user device **200** for the user device **200** to communicate with and send data to the server **100**, as described below. Rather, in this embodiment, the queue wait time estimation application requires the user to agree to enable the user device **200** to communicate with and send data to the server **100** in the background while the user device **200** is connected to a suitable network, regardless of whether the queue wait time estimation application is open on the user device **200**.

Responsive to connecting to a suitable wireless network at diamond **302**, the user device **200** sends, to the server **100** and via one of the network interfaces **220** and **240**, a request to establish wireless communication, as block **304** indicates. The user device **200** establishes wireless communication with the server **100**, as block **306** indicates.

Afterward, the user device **200**: (1) periodically sends, to the server **100** and via one of the network interfaces **220** and **240**, location data, as block **308** indicates; and (2) periodically receives, from the server **100** and via one of the network interfaces **220** and **240**, establishment data, as block **310** indicates. The user device **200** may send the location data to the server **100** at any suitable points in time, such as (but not limited to) responsive to new or updated location data being received or determined by the user device **200**, at

particular time intervals, or according to a predetermined schedule. Periodically as used herein is therefore not limited to regular intervals, and can encompass irregularly-spaced points in time. In this example embodiment, the location data includes the absolute position on Earth of the user device **200** that the user device processor **205** determines based on geolocation data the GPS receiver **225** receives. The location data may include, for instance, the GPS coordinates of the user device **200**. The location data may also include a timestamp representing the time at which the user device **200** sends the location data to the server **100**. The user device **200** may periodically receive the establishment data from the server **100** at any suitable points in time, such as (but not limited to) responsive to a user-input request for establishment data, responsive to the queue wait time estimation system application opening on the user device **200**, responsive to the server **100** updating the establishment data, at particular time intervals, or according to a predetermined schedule.

In this embodiment, the user device **200** periodically sends the location data and periodically receives the establishment data until ceasing wireless communication with the server **100**. This enables the server **100** to continuously monitor the location of the user device **200** to determine when an arrival event or a departure event occurs to indicate a user has arrived at or departed from an establishment, as described below with respect to FIGS. **5A** and **5B**.

Additionally, after the user device **200** establishes wireless communication with the server **100**, the user device **200** monitors: (1) for receipt, from the server **100** and via one of the network interfaces **220** and **240**, of a request for sensor data, as diamond **312** indicates; and (2) the status of the wireless communication with the server **200**, as diamond **314** indicates.

Responsive to receiving, from the server **100** and via one of the network interfaces **220** and **240**, a request for sensor data, the user device **200** periodically sends to the server **100** and via one of the network interfaces **220** and **240**: (1) magnetometer data the magnetometer **250** obtains, as block **316** indicates; and (2) accelerometer data the accelerometer **245** obtains, as block **318** indicates. The periodic sending may occur at any suitable points in time, such as (but not limited to) responsive to new or updated sensor data being received or determined, at particular time intervals, or according to a predetermined schedule. The magnetometer data may include the direction in which the user device **200** is pointing relative to the Earth's true North, which the user device processor **205** determines based on the direction of the Earth's magnetic North sensed by the magnetometer **250**. The accelerometer data may include raw acceleration data detected by the accelerometer **245**, which the server **100** processes, or already processed raw acceleration data, such as an estimated quantity of steps the user has taken since the last data transmission (or during a suitable time period).

The user device **200** also monitors for receipt, from the server **100** and via one of the network interfaces **220** and **240**, of a request to stop sending the sensor data, as diamond **320** indicates. The user device **200** periodically sends the magnetometer data and the accelerometer data to the server **100** until receiving a request to stop sending the sensor data or until ceasing wireless communication with the server **100**. This enables the server **100** to continuously monitor this sensor data to determine when a queue exit event occurs to indicate the user has exited the queue and is idle at an establishment, as described below with respect to FIGS. **5A** and **5B**.

Responsive to receiving a request to stop sending the sensor data at diamond 312, the user device 200 stops sending the magnetometer data and the accelerometer data to the server 100, as block 322 indicates. The user device 200 again begins monitoring for receipt, from the server 100 and via one of the network interfaces 220 and 240, of a request for sensor data, as diamond 312 indicates (as well as continuing to monitor the status of the wireless communication with the server 100, as diamond 314 indicates).

Responsive to determining that the user device 200 is no longer in communication with the server 100 at diamond 314, the process 300 ends. The user device 200 and the server 100 may lose communication for a variety of reasons, such as either or both of their network interfaces shutting down. In certain embodiments, if the user device 200 and the server 100 lose the ability to communicate with one another (such as before the user device 200 receives the request to stop sending the sensor data), the user device 200 continues to collect the sensor data and locally stores the sensor data until communication is reestablished with the server 100. At that point, the user device 200 sends the collected and locally stored sensor data to the server 100.

2.2 User Device/Server Interaction-Server Perspective

FIGS. 5A and 5B are (collectively) a flowchart of an example process 400 of operating the queue wait time estimation system 10 from the perspective of the server 100. In various embodiments, a set of instructions stored in the server memory 110 and executed by the server processor 105 represents the process 400. Although the process 400 is described with reference to the flowchart shown in FIGS. 5A and 5B, many other processes of performing the acts associated with this illustrated process 400 may be employed. For example, the order of certain of the illustrated blocks or diamonds may be changed, certain of the illustrated blocks or diamonds may be optional, or certain of the illustrated blocks or diamonds may not be employed.

The process 400 is explained below for a single user device, though the server is configured to simultaneously perform process 400 for hundreds, thousands, tens of thousands, or hundreds of thousands of user devices in an overlapping manner.

The process 400 begins with the server 100 monitoring for receipt, from the user device 200 and via the network interface 115, of a request to establish wireless communication with the user device 200, as diamond 402 indicates. Responsive to receiving a request to establish wireless communication, the server 100 establishes wireless communication with the user device 200, as block 404 indicates.

Afterward, the server 100: (1) periodically receives, from the user device 200 and via the network interface 115, location data, as block 406 indicates; and (2) periodically sends, to the user device 200 and via the network interface 115, establishment data, as block 408 indicates. The location data and the establishment data are described above.

The server 100 periodically receives the location data and periodically sends the establishment data until ceasing wireless communication with the user device 200, as described above. This enables the server 100 to continuously monitor the location of the user device 200 to determine when an arrival event or a departure event occurs to indicate a user has arrived at or departed from an establishment, as described below.

Additionally, after the server 100 establishes wireless communication with the user device 200, the server 100 monitors: (1) for the occurrence of an arrival event based on the location data received from the user device 200, as

diamond 410 indicates; and (2) the status of the wireless communication with the user device 200, as diamond 412 indicates.

An occurrence of an arrival event indicates to the server 200 that the user (with her user device 200) has arrived at an establishment. In this example embodiment, the arrival event occurs when the location data received from the user device 200 indicates that the user device 200 has been located within a designated vicinity of an establishment for a designated period of time. Specifically, in this example embodiment, the server 100 periodically or continuously cross-references the GPS coordinates of the user device 200 with an establishment database that stores the GPS coordinates of the epicenter (or any other portion) of each of multiple establishments. The server 100 determines that the arrival event occurs when the GPS coordinates of the user device 200 have been within the designated vicinity of the GPS coordinates of the epicenter of one of the establishments for the designated period. For instance, the server 100 determines that the arrival event occurs for Restaurant A when the GPS coordinates of the user device 200 have been within a 30 foot radius of the GPS coordinates of the epicenter of Restaurant A for 10 seconds.

The designated vicinity may be defined in any suitable manner, such as by any suitably shaped area (e.g., a circular area, a rectangular area, or an oval area), and the designated vicinity may take any suitable size(s). Different establishments may have different designated vicinities. For instance, in one example embodiment, a 10,000 square foot gym has a larger designated vicinity than a 750 square foot coffee shop.

The designated period may be any suitable period of time. The designated period is large enough to ensure that the server 100 is receiving accurate location data from the user device 200 to weed out false positives. For instance, GPS is at times inaccurate, so the designated period provides a buffer against the server 100 receiving inaccurate GPS coordinates and determining that the user device 200 is in an establishment when in reality it's not. Different establishments may have different designated periods.

Returning to the process 400, responsive to determining that the arrival event occurred for a particular establishment at diamond 410, the server 100 determines that the user (and her user device 200) has entered the queue in the establishment, as block 414 indicates. That is, the server 100 assumes the user entered the queue at the establishment upon arriving at the establishment. The server 100 increments a running queue wait time estimation system user count for the establishment that is stored in a database (such as on the server memory 110), as block 416 indicates. As described below, the server 100 uses the running queue wait time estimation system user count for a particular establishment to estimate how many patrons are inside the establishment at a given point in time. The server 100 also stores the time at which the arrival event occurred (such as by storing a timestamp received from the user device 200) and the identity of the establishment (such as an address of the establishment or the GPS coordinates of the establishment) in a database (such as one stored on the server memory 110) as the arrival time, as block 418 indicates.

The server 100 determines whether the establishment is queue-wait-time eligible, as diamond 420 indicates. The server 100 is configured to determine estimated queue wait times for queue-wait-time eligible establishments, but is not configured to determine estimated queue wait times for establishments that are not queue-wait-time eligible. Queue-wait-time eligible establishments include establishments for

which the queue wait time estimation system can estimate the amount of time people will be waiting (such as in a queue) for a service. In this example embodiment, the server **100** determines whether the establishment is queue-wait-time eligible by referencing the establishment database, which includes an entry for each establishment that indicates whether the establishment is queue-wait-time eligible. In other embodiments, all establishments are queue-wait-time eligible, and the server **100** does not perform step **420**.

Responsive to determining that the establishment is not queue-wait-time eligible at diamond **420**, the process **400** proceeds to diamond **430**, described below. That is, if the establishment is not queue-wait-time eligible, the server **100** does not monitor for the occurrence of the queue exit event, but instead monitors for the occurrence of the departure event.

On the other hand, responsive to determining that the establishment is queue-wait-time eligible at diamond **420**, the server **100** sends, to the user device **200** and via the network interface **115**, a request for sensor data, as block **426** indicates. Responsive to sending the request for sensor data, the server **100** periodically receives, from the user device **200** and via the network interface **115**: (1) accelerometer data, as block **422** indicates; and (2) magnetometer data, as block **424** indicates. The accelerometer data and the magnetometer data are described above. In other embodiments, the server **100** requests and receives any other suitable data collected from any sensor(s) of the user device **200** or determined based on data collected from any sensor(s) of the user device **200**.

After sending the request for sensor data, the server **100** monitors for: (1) an occurrence of a queue exit event based on the accelerometer data and the magnetometer data received from the user device **200**, as diamond **428** indicates; and (2) an occurrence of the departure event based on the location data received from the user device **200**, as diamond **430** indicates.

An occurrence of the queue exit event indicates to the server **200** that the user (with her user device **200**) has exited the queue and remains in the establishment (e.g., is idly sitting in the establishment). In this example embodiment, the queue exit event occurs when the following two triggering events occur within a particular time period: (1) the accelerometer data indicates that the user has taken fewer than a designated quantity of steps within a first designated time period; and (2) the magnetometer data indicates that the direction in which the user device **200** is pointing has not changed more than a designated amount within a second designated time period. The particular time period during which the two triggering events must occur for the queue exit event to occur may be any suitable time period. The first and second designated time periods may be of any suitable length, may be the same or different, may completely overlap, may partially overlap, or may not overlap, depending on the embodiment. The designated quantity of steps may be any suitable quantity of steps. For example, the queue exit event occurs when: (1) the accelerometer data indicates the user has taken fewer than 2 steps within a 60 second time period; and (2) the magnetometer data indicates that the user device **200** has been pointed within the same a 5 degree range (or any other suitable range) during that same 60 second time period.

Responsive to determining that the queue exit event occurred at diamond **428**, the server **100** determines that the user (and her user device **200**) has exited the queue and remains in the establishment, as block **432** indicates. The server **100** stores the time at which the queue exit event

occurred in a database (such as one stored on the server memory **110**) as the queue exit time, as block **434** indicates.

Following an occurrence of the queue exit event at diamond **428**, the server **100** monitors for an occurrence of the departure event based on the location data received from the user device **200**, as diamond **430** indicates.

An occurrence of the departure event indicates to the server **100** that the user (with her user device **200**) has departed the establishment. In this example embodiment, the departure event occurs when the location data received from the user device **200** indicates that the user device **200** has been located outside of the designated vicinity of the establishment for a designated period. For example, the departure event occurs for Restaurant A when the GPS coordinates of the user device **200** have been outside of a 30 foot radius of the GPS coordinates of the epicenter of Restaurant A for 180 seconds.

The designated vicinity may be defined in any suitable manner, such as by any suitably shaped area (e.g., a circular area, a rectangular area, or an oval area), and the designated vicinity may take any suitable size(s). Different establishments may have different designated vicinities. For instance, in one example embodiment, a 10,000 square foot gym has a larger designated vicinity than a 750 square foot coffee shop. The designated vicinity for the departure event may be the same as or different from the designated vicinity for the arrival event.

The designated period of time may be any suitable period. The designated period is large enough to ensure that the server **100** is receiving accurate location data from the user device **200** to weed out false positives. For instance, GPS is at times inaccurate, so the designated period provides a buffer against the server **100** receiving inaccurate GPS coordinates and determining that the user device **200** is in an establishment when in reality it's not. Different establishments may have different designated periods. The designated period for the departure event may be the same as or different from the designated period for the arrival event.

In this example embodiment, since the departure event is based on location data and not sensor data, large fluctuations in the sensor data that occur after the queue exit event—such as those that would occur when a patron is walking to the soda fountain to get a refill—do not trigger the departure event and therefore do not affect the estimated queue wait time of the establishment.

Returning to the process **400**, responsive to determining that the departure event occurred for a particular establishment at diamond **430**, the server **100** determines that the user (and her user device **200**) has departed the establishment, as block **436** indicates. The server **100** decrements the running queue wait time estimation system user count (explained above) for the establishment, as block **438** indicates. The server **100** also stores the time at which the departure event occurred (such as by storing a timestamp received from the user device **200**) in a database (such as one stored on the server memory **110**) as the departure time, as block **440** indicates. Additionally, the server **100** sends, to the user device **200** and via the network interface **115**, a request to stop sending sensor data, as block **442** indicates.

At this point, the user device again begins monitoring for an occurrence of the arrival event (as well as continuing to monitor the status of the wireless communication with the user device **200**, as diamond **412** indicates). Responsive to determining that the server **100** is no longer in communication with the user device **200** at diamond **412**, the process **400** ends.

2.3 Determining Establishment Data

The server **100** uses the data gathered during the process **400** for multiple user devices **200** to determine two types of establishment data for an establishment: (1) an estimated queue wait time (if applicable); and (2) an estimated total quantity of patrons in the establishment (if applicable).

2.3.1 Determining Estimated Queue Wait Time

For each occurrence of the arrival event and subsequent departure event for each establishment—called a “wait event”—the server **100** is configured to use the arrival time, the departure time, and (if applicable) the queue exit time to determine a queue wait time. The queue wait time is a period of time that represents the (estimated) amount of time the user spent waiting in the queue at that establishment for that particular wait event.

For wait events in which the queue exit event occurred, the server **100** determines the queue wait time by determining the difference between the arrival time and the queue exit time. This reflects, for example, situations in which the user remains in the establishment after receiving a service (e.g., sits down to eat after ordering and receiving her food at a fast-food restaurant). The server **100** stores the determined queue wait time in a suitable database.

Here’s an example. Evelyn powers on her mobile phone, on which the queue wait time estimation application is installed. The mobile phone establishes wireless communication with the server. Evelyn grabs her backpack and heads to class. As Evelyn walks to class, her mobile phone periodically sends the mobile phone’s GPS coordinates to the server. The server monitors the mobile phone’s GPS coordinates and references them against an establishment database.

Evelyn decides to stop for coffee at Coffee Shop C before class. Evelyn walks inside and gets in the queue. After 10 seconds pass, the server determines that the arrival event occurred because the GPS coordinates of Evelyn’s mobile phone have been within a 30 foot radius of the GPS coordinates of the epicenter of Coffee Shop C for 10 seconds. The server determines an arrival time of 9:00 a.m. Evelyn’s mobile phone begins sending accelerometer data and magnetometer data to the server, and the server monitors this data.

Evelyn orders her coffee, picks it up, and decides to sit down and catch up on some reading. She places her mobile phone on the table. After 60 seconds pass, the server determines that the queue exit event occurred because: (1) Evelyn hasn’t taken any steps in 60 seconds; and (2) Evelyn’s mobile phone has been pointing in the same direction for the same 60 seconds. The server determines a queue exit time of 9:06 a.m.

Evelyn finishes up and leaves Coffee Shop C. After 10 seconds pass, the server determines that the departure event occurred because the GPS coordinates of Evelyn’s mobile phone have been outside of a 30 foot radius of the GPS coordinates of the epicenter of Coffee Shop C for 10 seconds. This completes the wait event. The server determines a departure time of 9:20 a.m. In this example, the queue wait time is 6 minutes (the difference between the arrival time (9:00 a.m.) and the queue exit time (9:06 a.m.)). Evelyn spent a total of 20 minutes in Coffee Shop C (the difference between the arrival time (9:00 a.m.) and the departure time (9:20 a.m.)).

For wait events in which the queue exit event did not occur, the server **100** determines the queue wait time by determining the difference between the arrival time and the departure time. This reflects, for example, situations in which the user does not remain in the establishment after

receiving a service (e.g., takes her food to go after ordering and receiving her food at a fast-food restaurant). The server **100** stores the determined queue wait time in a suitable database in association with the establishment.

For example, assume that Evelyn (from the above example) decided not to sit in Coffee Shop C, but to leave immediately after picking up her coffee. After 10 seconds pass, the server determines that the departure event occurred because Evelyn’s mobile phone has been outside a 30 foot radius of the GPS coordinates of the epicenter of Coffee Shop C for 10 seconds. This completes the wait event. The server determines a departure time of 9:06 a.m. In this example, the queue wait time is 6 minutes (the difference between the arrival time (9:00 a.m.) and the departure time (9:06 a.m.)). Evelyn spent a total of 6 minutes in Coffee Shop C (the difference between the arrival time (9:00 a.m.) and the departure time (9:06 a.m.)).

As the server **100** determines and stores individual queue wait times for wait events at a given establishment, the server **100** uses those queue wait times to determine the real-time or nearly real-time estimated queue wait time for that establishment. The server **100** periodically updates the estimated queue wait time for each establishment to ensure accuracy (such as at regular intervals, according to a pre-determined schedule, or whenever another wait event occurs for an establishment), and stores the updated estimated queue wait time in association with that establishment in a suitable database. When the server **100** receives a request for the estimated queue wait time from a user device **200** for a particular establishment, the server **100** determines the estimated queue wait time by referencing the establishment in the database and sends the estimated queue wait time to the user device **200** for display. This means that an estimated queue wait time sent to a user is a real-time or nearly real-time value. This provides the user an accurate estimate of the time the user will be waiting in line should the user visit the establishment shortly after viewing the estimated queue wait time.

The queue wait time system may also determine, store, and send to users average estimated queue wait times for different periods of time. For instance, for a particular establishment, the queue wait time system may determine and store average estimated queue wait times for each hour of the day and/or for each day of the week. This enables users to plan ahead and determine what the estimated queue wait time will be at a particular time on a particular day.

In certain embodiments, the estimated queue wait time for an establishment for a particular period of time is equal to the mean of the individual wait times for the wait events for that establishment that occur within that block of time. For instance, if 7 wait events have occurred between 1:00 p.m. and 2:00 p.m. and the queue wait times for those wait events were 6 minutes, 5 minutes, 7 minutes, 8 minutes, 9 minutes, 5 minutes, and 4 minutes, the queue wait time estimation system would determine an estimated queue wait time of about 6.3 minutes. In some embodiments, the estimated queue wait time includes a range. In one such embodiment, the queue wait time estimation system determines the lower end of the range by subtracting one (or any suitable quantity of) standard deviation from the mean and determines the upper end of the range by adding one (or any suitable quantity of) standard deviation to the mean. In the above example, the standard deviation of about 1.8, so the estimated queue wait time range is 4.5 minutes to 8.1 minutes.

In other embodiments, the estimated queue wait time for an establishment is equal to the rolling mean of the queue wait times of a designated quantity of the most recent wait

events for that establishment. For instance, if the designated quantity is three and the queue wait times for the three most recent wait events are 9 minutes, 5 minutes, and 4 minutes, the queue wait time estimation system would determine an estimated queue wait time of 6 minutes.

In other embodiments, the server **100** uses queuing theory to determine the estimated queue wait time for an establishment for a given time period. In one example embodiment, the server **100** first determines: (1) an arrival rate, which represents the quantity of arrival events that occurred during the time period (determined based on location data received from the user devices); and (2) a service rate, which represents the quantity of queue exit events that occurred during the time period (determined based on sensor data received from the user devices). The server **100** uses Equations 1 to 5 below to determine the estimated queue wait time for the establishment. In these equations: (1) μ represents the arrival rate (units of people per hour); (2) λ represents the service rate (units of people per hour); (3) r represents the utilization rate and has (no units); (4) P_0 represents the probability that the system is idle (i.e., that no one is being served or in line) (no units); (5) L represents the expected number of people being served and/or in line; (6) L_q represents the expected quantity of people in the queue; and (7) W_q represents the estimated queue wait time for a new arrival in the queue.

$$r = \lambda / \mu \quad (1)$$

$$P_0 = (1 - r) \quad (2)$$

$$L = \lambda / (\mu - \lambda) \quad (3)$$

$$L_q = \lambda^2 / (\mu(\mu - \lambda)) \quad (4)$$

$$W_q = L_q / \lambda \quad (5)$$

Here's an example. Assume the arrival rate μ is 5 and the service rate λ is 4 for a particular time period. In this example: (1) $r=0.8$; (2) $P_0=0.2$; (3) $L=4$; (4) $L_q=3.2$; and (5) $W_q=0.8$ hours.

The system in the above example assumes a Poisson process applies (which means the rate of arrival is not cyclical but random, but the system mathematically models it so it is cyclical).

The queue wait time estimation system may use any other suitable manner(s) of data manipulation to determine the estimated queue wait time for an establishment based on the determined individual queue wait times, such as (but not limited to) exponential smoothing, time series analyses such as the Box-Jenkins approach, X-11, and other casual models such as regression models and econometrical models.

In various embodiments, the queue wait time estimation system uses inference and signal processing techniques applied to mobile pedometer and accelerometer data. It attempts to infer and aggregate these statistics across venues with different traffic patterns and for users of different behavioral patterns. It relies on a low-pass filter applied to discretized pedometer data streams, followed by pattern matching against common prototypes of customer movement in establishments. This method is robust to noise and scales easily in both the dimensions of user and venue entries.

2.3.2 Determining the Estimated Total Quantity of Patrons in an Establishment

As explained above, as arrival and departure events occur for an establishment, the server **100** increments and decrements the running queue wait time estimation system user count for the establishment. But since in some instances all patrons of the establishment may not use the queue wait time

estimation system, the running queue wait time estimation system user count may not accurately reflect the actual total quantity of patrons in the establishment.

To solve this problem, the server **100** uses a confidence interval population calculation to determine the estimated total quantity of patrons in the establishment based on the running queue wait time estimation system user count for that establishment.

3. Variations

In certain embodiments, the queue wait time estimation system is configured to filter out and ignore queue wait times determined to be unreasonably short or long. For instance, for a particular establishment, the queue wait time estimation system is configured to ignore a queue wait time that is a particular quantity of standard deviations outside of the estimated queue wait time at the point in time the server **100** determined that queue wait time. For example, the estimated queue wait time between 12:00 p.m. and 1:00 p.m. at Restaurant X is 9 minutes with a standard deviation of 2 minutes. If the server **100** determines a queue wait time of 1 minute at 12:30 p.m., the server **100** filters out and ignores that queue wait time (i.e., doesn't use it to update the estimated queue wait time) because that queue wait time is more than 2 standard deviations outside of the 9 minute estimated queue wait time at 12:30 p.m. Any suitable quantity of standard deviations may be used (e.g., 1, 2, or 3 standard deviations).

In some embodiments, the queue wait time estimation system is configured to filter out and ignore queue wait times attributed to those who work at the establishments. For instance, a waiter may enter the establishment and work a 3-hour shift in which the waiter is constantly moving before sitting down for a 15-minute break. In this example, the worker's queue wait time would be 3 hours. The queue wait time estimation system is configured to filter out this unreasonably long queue wait time as described above. In another embodiment, the queue wait time estimation system monitors for sensor data that fluctuates for at least a designated period of time, and ignores any such sensor data.

In various embodiments, the queue wait time estimation system includes one or more notification features. One example notification feature enables the user to input a request to the queue wait time estimation system to notify the user at a particular time to visit a particular establishment. The queue wait time estimation system may notify the user in any suitable manner, such as by causing an image to be displayed on the user device's display device, causing the user device to output an audible alarm, causing an email to be sent to the user's email account, or causing a text message to be sent to the user. For instance, a user may request the queue wait time estimation system to cause the user device to output an alarm and display an image of Restaurant A at 6:30 p.m. to remind the user she has a 7:00 p.m. reservation at Restaurant A.

Another example notification feature enables the user to input a request to the queue wait time estimation system to notify the user when the upper or lower bound estimated queue wait time for a particular establishment falls below a certain threshold. The queue wait time estimation system may notify the user in any suitable manner, such as any of those listed above. For instance, a user may request the queue wait time estimation system to cause the user device to output an alarm and display an image of Restaurant A when the upper bound of the estimated queue wait time for Restaurant A falls below 15 minutes.

Another example notification feature enables the user to input a request to the queue wait time estimation system to

notify the user when the estimated total quantity of patrons in a particular establishment falls below a certain threshold. The queue wait time estimation system may notify the user in any suitable manner, such as any of those listed above. For instance, a user may request the queue wait time estimation system to cause the user device to output an alarm and display an image of Gym B when the estimated total quantity of patrons in Gym B falls below 20 patrons.

In certain embodiments, the queue wait time estimation system enables users to order items or services from establishments. For instance, in one example embodiment, the queue wait time estimation system enables users to order food from one or more restaurant establishments for delivery to a desired location or for pick-up at the establishment. In another example embodiment, the queue wait time estimation system enables users to order services such as dry-cleaning services and tailoring services.

In some embodiments in which the user device stores and executes a queue wait time estimation application, the queue wait time estimation application requires the user to agree to enable the queue wait time estimation application to run in the background and wirelessly communicate with—and send the location data to—the server. In certain embodiments, the queue wait time estimation application doesn't require the queue wait time estimation application to run in the background.

The user device described above is a mobile phone, and particularly a smartphone. The user device may be any suitable mobile device configured to wirelessly communicate with the server, such as (but not limited to) a tablet computing device, a personal digital assistant, a wearable computing device (such as a smartwatch), or a laptop computer.

In certain embodiments, the queue wait time estimation system is configured to determine, for a user, a table time via the difference between the queue exit time and the departure time. This is the amount of time the user is sitting at his table. The queue wait time estimation system could determine an estimated table time in a manner similar to that described above.

The queue exit event may be any suitable event that occurs based on data obtained by one sensor or multiple sensors.

In other embodiments, rather than determine the arrival time, the queue exit time, the queue wait time, and the departure time for a particular establishment using data obtained from a user's mobile device, the queue wait time estimation system uses multiple sensors in the establishment to do so. These sensors may be any suitable sensors, such as bi-directional sensors, infrared sensors, RFID sensors, or cameras coupled with body-counting algorithms that enable detection of the direction in which a person is traveling. Sensors placed at the entrance to the establishment and at the end of the queue enable the queue wait time estimation to use the time difference between entrance sensor trips and end-of-queue sensor trips to determine the queue wait time for a user. Integration with point-of-sale systems that enable tracking of transactions can also be used to determine the queue exit time.

In certain embodiments, a user can access and view the establishment data via a queue wait time estimation system website accessible via any suitable computing device (e.g., a desktop computer, a laptop computer, a tablet computing device, a mobile phone, or a wearable computing device). The computing device does not need to send location data or sensor data (and does not even need to be capable of sending this data) to the server of the wait time estimation system to

access and display the establishment data via the queue wait time estimation system website. In one such embodiment, the queue wait time estimation system requires a user to have the queue wait time estimation system installed on her user device to access and view the establishment data via the queue wait time estimation system website. For instance, the queue wait time estimation system requires the user to set up a user account (such as by entering a login or user identifier and a password) and install the queue wait time estimation system on her user device. The user can login to the queue wait time estimation system website using the login and password to access and view the establishment data via the website.

In various embodiments, the server can associate different types of establishments with different types of queue exit events that reflect the different natures of the establishments. For instance, in one embodiment, for a particular establishment (such as a dance club), a user may wait in a long, slow-moving line to enter, but after entering may be moving most of the time. In this embodiment, the queue exit event occurs when the following two triggering events occur within a particular time period: (1) the accelerometer data indicates that the user has taken more than a designated quantity of steps within a first designated time period; and (2) the magnetometer data indicates that the direction in which the user device is pointing has changed more than a designated amount within a second designated time period. The particular time period during which the two triggering events must occur for the queue exit event to occur may be any suitable time period. The first and second designated time periods may be of any suitable length, may be the same or different, may completely overlap, may partially overlap, or may not overlap, depending on the embodiment. The designated quantity of steps may be any suitable quantity of steps. For example, the queue exit event occurs when: (1) the accelerometer data indicates the user has taken more than 15 steps within a 60 second time period; and (2) the magnetometer data indicates that the user device 200 has not been pointed within the same a 5 degree range (or any other suitable range) during that same 60 second time period.

In various embodiments, the server can interface with an establishment's point-of-sale terminals to provide real-time (or nearly real-time) data regarding the establishment's queue wait times (or any other suitable metrics). This enables the server to provide various alerts to the point-of-sale terminals, such as when the queue wait time exceeds a particular threshold, to enable the employees to attempt to remedy the situation and reduce the queue wait time to increase customer satisfaction and increase throughput (and therefore profitability).

In certain embodiments, the server is configured to estimate the total quantity of patrons in an establishment that have a particular characteristic, such as a particular favorite sports team or a particular gender. As explained above, as arrival and departure events occur for an establishment, the server increments and decrements the running queue wait time estimation system user count for the establishment. In these embodiments, the server maintains similar counts for users with particular characteristics. For instance, the server increments a Team A fan count for an establishment every time an arrival event occurs for the establishment for a user whose favorite team is Team A and decrements the Team A fan count for the establishment every time a departure event occurs for the establishment for a user whose favorite team is Team A. The server may use a confidence interval population calculation (described above) to account for the fact that not all patrons in the establishment are users of the

system and estimate how many patrons in the establishment are fans of Team A. The server may determine a user's characteristics based on the user's profile with the system or a linked social media account to which the user has granted the server access.

Various changes and modifications to the present embodiments described herein will be apparent to those skilled in the art. Such changes and modifications can be made without departing from the spirit and scope of the present subject matter and without diminishing its intended advantages. It is therefore intended that such changes and modifications be covered by the appended claims.

The invention is claimed as follows:

1. A method of operating a queue wait time estimation system, the method comprising:

establishing wireless communication with a user device; periodically receiving, by a network interface and from the user device, location data associated with the user device;

monitoring, by a processor, the location data for an occurrence of an arrival event associated with an establishment;

responsive to an occurrence of the arrival event:

storing, in a memory device, an arrival time; monitoring, by the processor, the location data for an occurrence of a departure event associated with the establishment;

receiving, by the network interface and from the user device, sensor data determined based on feedback from at least one sensor of the user device;

monitoring, by the processor, the sensor data for an occurrence of a queue exit event;

responsive to an occurrence of the queue exit event, storing, in the memory device, a queue exit time; and

responsive to an occurrence of the departure event, storing, in the memory device, a departure time;

determining, by the processor, a queue wait time based on at least the arrival time and the queue exit time; and

determining, by the processor and based in part on the queue wait time, establishment data including an estimated queue wait time for the establishment;

wherein the sensor data includes accelerometer data and magnetometer data.

2. The method of claim 1, wherein the location data includes global-positioning system (GPS) coordinates of the mobile device.

3. The method of claim 2, which includes determining, by the processor, that the arrival event associated with the establishment occurred responsive to determining that the GPS coordinates of the mobile device have been within a designated vicinity of GPS coordinates of the establishment for a designated period of time.

4. The method of claim 3, which includes determining, by the processor, that the departure event associated with the establishment occurred responsive to determining that the GPS coordinates of the mobile device have been outside of the designated vicinity of the GPS coordinates of the establishment for a second designated period of time following the occurrence of the arrival event.

5. The method of claim 1, which includes determining, by the processor, that the queue exit event occurred responsive to determining that: (1) the accelerometer data indicates that fewer than a designated quantity of steps have been taken within a first designated time period; and (2) the magnetometer data indicates that a direction in which the user device is pointed has not changed more than a designated amount for a second designated time period.

6. The method of claim 5, wherein the occurrence of the arrival event indicates that the user device has arrived at the establishment and entered the queue, the queue exit event indicates that the user device has exited the queue, and the departure event indicates that the user device has departed the establishment.

7. The method of claim 1, wherein the occurrence of the arrival event indicates that the user device has arrived at the establishment and entered the queue, the queue exit event indicates that the user device has exited the queue, and the departure event indicates that the user device has departed the establishment.

8. The method of claim 1, wherein the location data includes GPS coordinates of the mobile device and the sensor data includes accelerometer data and magnetometer data, and which includes:

determining, by the processor, that the arrival event occurred responsive to determining that the GPS coordinates of the mobile device have been within a designated vicinity of GPS coordinates of the establishment for a designated period of time;

determining, by the processor, that the departure event occurred responsive to determining that the GPS coordinates of the mobile device have been outside of the designated vicinity of the GPS coordinates of the establishment for a second designated period of time following the occurrence of the arrival event; and

determining, by the processor, that the queue exit event occurred responsive to determining that: (1) the accelerometer data indicates that fewer than a designated quantity of steps have been taken within a first designated time period; and (2) the magnetometer data indicates that a direction in which the user device is pointed has not changed more than a designated amount for a second designated time period.

9. The method of claim 8, wherein the queue exit event occurs when (1) and (2) occur within a third designated time period of one another.

10. A queue wait time estimation system comprising:

a processor;

a network interface; and

a memory that stores instructions that, when executed by the processor, cause the processor to:

establish wireless communication with a user device via the network interface; periodically receive, via the network interface and from the user device, location data associated with the user device;

monitor the location data for an occurrence of an arrival event associated with an establishment;

responsive to an occurrence of the arrival event: store an arrival time in the memory device; monitor the location data for an occurrence of a departure event associated with the establishment;

receive, via the network interface and from the user device, sensor data determined based on feedback from at least one sensor of the user device;

monitor the sensor data for an occurrence of a queue exit event; responsive to an occurrence of the queue exit event, store a queue exit time in the memory device; and

responsive to an occurrence of the departure event, store a departure time in the memory device;

determine a queue wait time based on at least the arrival time and the queue exit time; and

determine, based in part on the queue wait time, establishment data including an estimated queue wait time for the establishment;

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wherein the sensor data includes accelerometer data and magnetometer data.

11. The queue wait time estimation system of claim 10, wherein the location data includes global-positioning system (GPS) coordinates of the mobile device.

12. The queue wait time estimation system of claim 11, wherein the instructions, when executed by the processor, cause the processor to determine that the arrival event associated with the establishment occurred responsive to determining that the GPS coordinates of the mobile device have been within a designated vicinity of GPS coordinates of the establishment for a designated period of time.

13. The queue wait time estimation system of claim 12, wherein the instructions, when executed by the processor, cause the processor to determine that the departure event associated with the establishment occurred responsive to determining that the GPS coordinates of the mobile device have been outside of the designated vicinity of the GPS coordinates of the establishment for a second designated period of time following the occurrence of the arrival event.

14. The queue wait time estimation system of claim 10, wherein the instructions, when executed by the processor, cause the processor to determine that the queue exit event occurred responsive to determining that: (1) the accelerometer data indicates that fewer than a designated quantity of steps have been taken within a first designated time period; and (2) the magnetometer data indicates that a direction in which the user device is pointed has not changed more than a designated amount for a second designated time period.

15. The queue wait time estimation system of claim 14, wherein the occurrence of the arrival event indicates that the user device has arrived at the establishment and entered the queue, the queue exit event indicates that the user device has exited the queue, and the departure event indicates that the user device has departed the establishment.

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16. The queue wait time estimation system of claim 10, wherein the occurrence of the arrival event indicates that the user device has arrived at the establishment and entered the queue, the queue exit event indicates that the user device has exited the queue, and the departure event indicates that the user device has departed the establishment.

17. The queue wait time estimation system of claim 10, wherein the location data includes GPS coordinates of the mobile device and the sensor data includes accelerometer data and magnetometer data, and wherein the instructions, when executed by the processor, cause the processor to:

determine that the arrival event occurred responsive to determining that the GPS coordinates of the mobile device have been within a designated vicinity of GPS coordinates of the establishment for a designated period of time;

determine that the departure event occurred responsive to determining that the GPS coordinates of the mobile device have been outside of the designated vicinity of the GPS coordinates of the establishment for a second designated period of time following the occurrence of the arrival event; and

determine that the queue exit event occurred responsive to determining that: (1) the accelerometer data indicates that fewer than a designated quantity of steps have been taken within a first designated time period; and (2) the magnetometer data indicates that a direction in which the user device is pointed has not changed more than a designated amount for a second designated time period.

18. The queue wait time estimation system of claim 17, wherein the queue exit event occurs when (1) and (2) occur within a third designated time period of one another.

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